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Directivity of Underwater Sounds Generated in the Vicinity of Tidewater Glaciers

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BACKGROUND

In the last few years ambient noise oceanography was found to be a promising tool in the study of dynamic processes taking place in the vicinity of tidewater glaciers (eg Pettit, 2012, "Passive underwater acoustic evolution of a calving event", Ann. Glaciol., 53; Tegowski et al., 2012, "Spectral and statistical analyses of ambient noise in Spitsbergen Fjords and identification of glacier calving events", in Proc. of the 11th European Conference on Underwater Acoustics, Edinburgh, Scotland). However, there is a growing need to link specific acoustic signatures with corresponding natural sources, unambiguously. Laboratory experiments revealed high-frequency (> 1 kHz) characteristics of the noise produced by melting glacier ice (Blondel et al., 2013, "Laboratory analyses of transient ice cracking in growlers", in Proc. of the 1st International Conference and Exhibition on Underwater Acoustics, Corfu, Greece). Most recently, the results of the first research concerning directionality of underwater sounds in the Arctic fjord clearly showed that different physical mechanisms radiate noise in distinct spectral bands (Deane et al., 2014, "Directionality of the Ambient Noise Field in an Arctic, Glacial Fjord", J. Acoust. Soc. Am. 136, EL350).

APPROACH

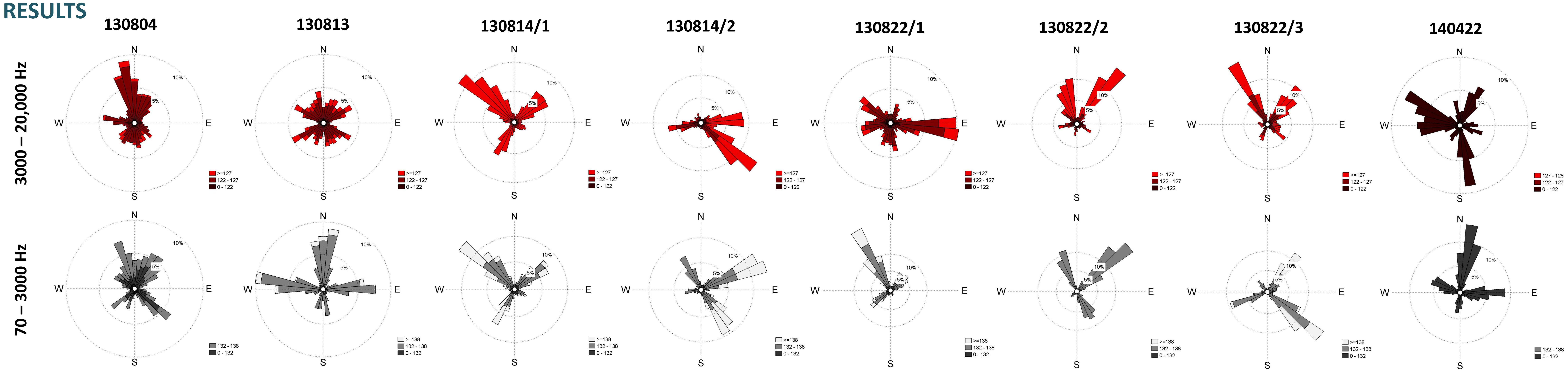
We used the Directional Acoustic Buoy (DAB) consisting of two broadband hydrophones spaced apart by 0.43 m on a horizontal axis, a magnetic compass and GPS sensor. To expand the first pilot study (Deane et al., 2014), recordings of underwater ambient noise, each lasting from 30 minutes to 1 hour, were taken in different parts of the Hornsund fjord, Spitsbergen in August, 2013 and April, 2014. The array was rotated through 90° every minute during the measurements to break its symmetry. Guided by the previous studies, analyses were performed separately for low (<3kHz) and high frequency noise (>3kHz). Delays of arrivals for a pair of hydrophones were obtained from the highest peaks of the cross-correlation function, found for short parts of the signals. Then, angles of arrivals were calculated for each section using this information and knowing the orientation of the array axis.

MAIN GOALS

We have already known that sounds of different frequencies propagate from different directions (Deane et al., 2014). This time the main objective was to find out, whether we can obtain any information about both distribution of glacial ice around the fjord and activity of individual tidewater glaciers, using these methods. We make assumption that, during relatively calm weather conditions, high frequency (3 – 20) kHz noise are produced in an Arctic, glacial fjord primarily by the melting ice.

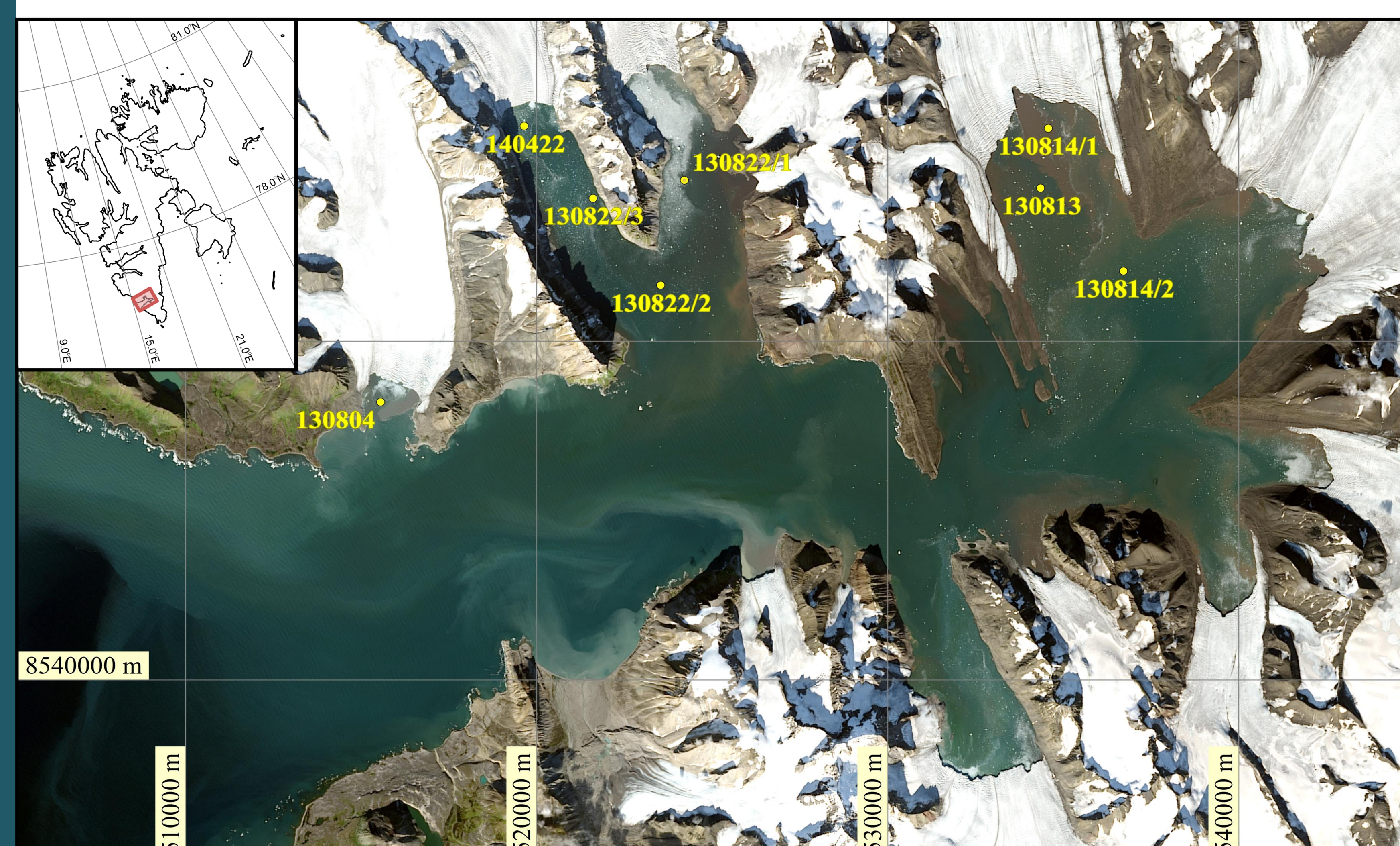
Directional Acoustic Buoy

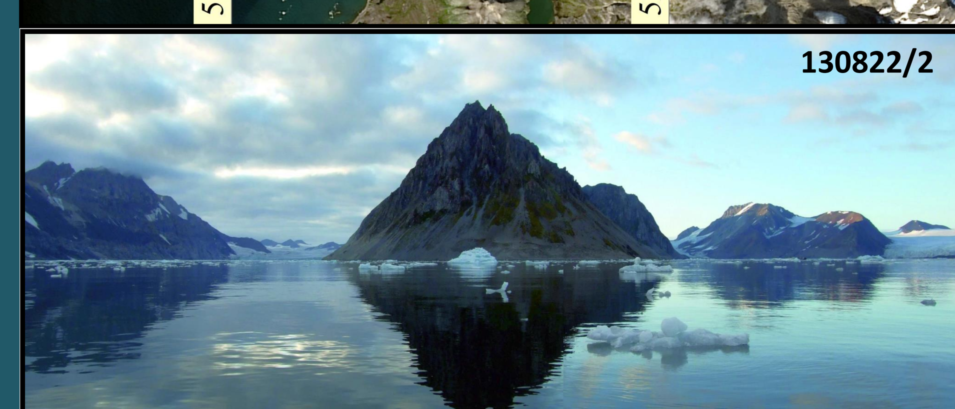
RESULTS



Rose plots of ambient noise directionality for each station. Top row shows high frequencies (3000-20,0000 Hz), while the lower represents low frequency sounds (70 – 3000 Hz). Color scales illustrate the proportion of arrivals with specific intensity, coming from each direction. Numerical values are the result of cross-corellation, normalized by the number of samples taken for calculations, and correspond to dB re 1 μPa^2.

STUDY SITE





Overview of the study site. Measurements were taken in the Hornsund Fjord, Spitsbergen, at the vicinity of tidewater glaciers. To minimize the impact of breaking waves on the ambient noise field, all recordings were made during calm weather conditions. Image on the left shows one of the stations, located on the crossroad between two glacial bays.

CONCLUSIONS AND FUTURE NEEDS

The results reveal that two-hydrophone horizontal array does, indeed, allow to investigate the dynamics of tidewater glaciers located in the Arctic fjord. In most cases, ambient noise at frequencies between 70 Hz and 3 kHz comes directly from the glacier fronts. Amplitudes of the upcoming arrivals are strongly dependent on the calving intensity and, most likely, activity of freswater outflows. Analysis of the recordings taken at the crossroads between several marine-terminating glaciers shows which one is producing the greatest amount of icebergs, in a given period of time. These findings demonstrate that acoustic monitoring, with the application of hydrophone arrays, can provide quantitative information about the activity of individual tidewater glaciers. The question is if we can also detect, which part of the ice cliff is more active (see rose plot for 130814/1). For higher frequencies, ranging from 3 to 20 kHz, noise sources seem to be more variable , so the ambiguity of the array was not always resolvable. Despite this fact, the distribution of the floating chunks of ice around the array is quite well illustrated on the rose plots, indicating dominant directions. This conclusion is based on the video recordings and notes made at the time of measurements. What is interesting, high and low frequency sounds come from roughly the same directions, when recordings are taken very close to the glacier front and the sea surface is almost free of drifting ice.

Similar research should be conducted in different fjords and bays, with the application of more than just two hydrophones, to test the method in different environmental regimes and avoid ambiguity in determining directions to the sources. Moreover, it would be extremely important to link acoustic recordings with quantitative glacier, oceanographic and meteorological measurements. Radar imaging or stereo-photography can provide essential information about the ice distribution along the fjord, required to draw more quantitative conclusions. Another important aspect is the sound propagation, which seems to be very complicated in the complex Arctic environment. New models are needed to find propagation patterns and take them into account during the subsequent studies.

ACKNOWLEDGEMENTS

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